SAMI 8400701

STRAT MISSILER

A

STRATEGIC MISSILE (ICBM/SLBM)

ANALYSIS COMPUTER MODEL

20 June 1979

Assistant Chief of Staff
Studies and Analyses
Headquarters United States Air Force

23420

Table of Contents

List of Figures

List of Tables

STRAT MISSILER SUMMARY

INTRODUCTION

STRAT MISSILER is a systemized grouping of computer subsystems for evaluating the effectiveness of strategic missile forces. Types of issues this model will address are force survivability, force sizing, and force characteristics. This computer program, inter alia, may assist the analyst in performing two principal functions:

1) Producing a realistic strategic plan incorporating the primary ICBM/SLBM physical and operational constraints.

2) Providing a net assessment of the effectiveness of the forces participating in the strategic plan.

The model, STRAT MISSILER, possesses the flexibility to treat a broad spectrum of strategic missions and missile systems. Model design emphasizes (1) the realistic modeling of constraints and (2) the acceptance of analyst controls.

Although the model does not permit a discrete-event simulation of a two-sided strategic exchange, it does provide the capability to evaluate the expected number of missiles surviving a counterforce strike. This permits one to study multi-strike scenarios involving two or more combatants. Further, STRAT MISSILER evaluates the probability of surviving the following four sources of weapon attrition:

- o Prelaunch attack } for each missile
- o Attack during flyout
- o Defense penetration } for each RV
- o Fratricide

The model utilizes the probability of weapon survival in computing the compound damage expectancy(CDE) achieved by the missile weapons against an installation target base (including population).

In operation, each STRAT MISSILER subsystem accepts a set of controls supplied by the analyst and each module obtains all needed modeling data from an external data base. There are no program internal algorithms or data items that are unique to specific countries, strategic missions, or weapon systems. Table 1 defines the maximum program capacity for a single execution and the attached glossary provides a reference for

unfamiliar terms.

Table 1 - Maximum STRAT MISSILER Capacity for a Single Execution

Targets Target islands	6,000
Aimpoints	10,000
Aimpoints per target island	1,000
Installations	50,000
Installations per parget island	1,000
Target categories	100
Target types per category	10
Planner segments	60
Defense sites	600
Missiles	
RVs	20,000
Missiles	3,000
Missile systems	25
Configurations	35
RVs per missile	50
Penetration aids per missile	50
Force elements	90
Aircraft (Allocation only)	
Aircraft weapon types	10
Weapon systems (missile systems and aircraft weapon types)	25

1.0 Description of STRAT MISSILER Subsystems

STRAT MISSILER comprises seven subsystems:

- o DMS Interface
- o Model Data Generation
- o Accessibility
- o Allocation
- o Assignment
- o Scheduling
- o Analysis

Model Data Generation and Accessibility: Initialization Subsystem

Allocation, Assignment and Scheduling: Plan-Generation Subsystems

Accessibility, Allocation, Assignment, Scheduling and Analysis: Analytical Subsystems

Initialization subsystems are stand-alone programs that aid the analyst by generating information needed for subsequent model operations. Their output is stored on a common data base to reduce the frequency of program execution. Plan-generation subsystems produce a timed laydown of general missile sorties in three steps: distribute weapons to aimpoints; form accessible

missile sorties; assign launch times to missile sorties. The Analysis subsystem evaluates the results at each step of the plan-generation process by computing measures of effectiveness such as target coverage, CDE, and counter-military potential. The following sections discuss each of the subsystems in more detail

1.1 DMS Interface Subsystem

The DMS Interface subsystem consists of two computer programs that perform all operations related to the STRAT MISSILER data base, which is controlled by the Advanced Penetration Model (APM) data base management system (DMS). The DMS Interface retrieves control and modeling data from the data base, performs limit tests on modeling parameters,[7] provides defaults for missing control parameters, and stores solution data in the data base.

1.2 Model Data Generation Subsystem

The Model Data Generation (MDG) subsystem is a stand-alone module which generates aimpoint and evaluation point representations of mobile-based missile systems. This subsystem treats five basing modes (shelter-based, trench-based, land area-mobile, sea-mobile, and air-mobile), computing the following:

1) Trench or shelter locations for geometries specified.

2) Aimpoint locations to be used in attacking the force element operating region as it is perceived by the attacker.

3) Evaluation points to be used in determining the CDE achieved by the attacker against the actual operating region.

4) CDE that would be achieved if an attacker placed a nominal weapon on each aimpoint.

Figure 1 illustrates the generation of shelters by MDG. The number of rows and columns, the separation between shelters, the coordinates of the center, and an azimuth providing the orientation are the defining parameters of a shelter based mobile area. The shelter separation may be supplied either as a distance in nautical miles or in terms of a scale factor applied to a weapon radius. This weapon radius is computed using input characteristics of a nominal attacking weapon and shelter hardness.

Given the above inputs, MDG calculates the latitude and

longitude of each shelter. The shelters are usually arranged on a rectangular grid as shown in Figure 1, but one control option will offset alternate rows by a specified distance. Aimpoints are placed on the shelters, based on the assumption that the attacker knows the shelter locations but does not know which shelters are occupied or the aimpoints may be placed midway between shelters, thereby allowing the analyst to test the tactic of using high-yield weapons that might damage multiple shelters.

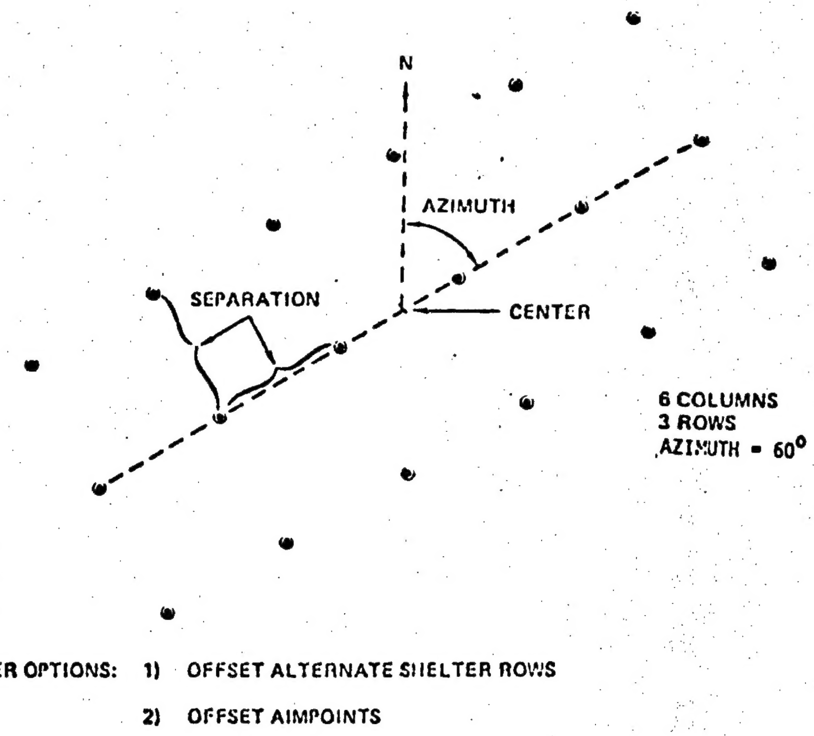


Figure 1 - STRAT MISSILER Generated Shelters

MDG's treatment of trenches is analogous to the shelter process just described. The other mobile-based modes are modelled differently in order to account for the attacker's uncertainty in identifying opponent's specific launch locations. MDG represents mobile bases (land area mobile, sea-mobile, and air-mobile) by processing two operating regions: the actual operating region that contains all of the potential launch locations (evaluation points) and the perceived operating region that the attacker believes he must destroy (aimpoints). STRAT MISSILER does not constrain the degree of overlap between the perceived and actual operating regions, thereby modeling the attacker's uncertainty in locating the mobile-based missiles.

Figure 2 illustrates this process for the special case of rectangular operating regions. The analyst defines the boundaries of the operating regions by supplying sets of latitude-longitude pairs (maximum of ten) defining the extreme points of each region. The subsystem then creates a network of points (aimpoints and evaluation points) to cover the respective region. Additionally specified is the mesh size for each network, either as a distance in nautical miles or in terms of a weapon-radius factor (for sea-mobile systems a damage radius based on level of impairment, submarine type, and operating depth is used rather than the weapon radius, which is calculated using the physical vulnerability number system).

Allocation, Assignment, and Analysis use the points created by MDG for the perceived operating region as aimpoints for hostile sorties attacking the mobile base. Analysis uses the evaluation points of the actual operating region in computing the damage expectancy suffered by the mobile base when the aimpoints are attacked.

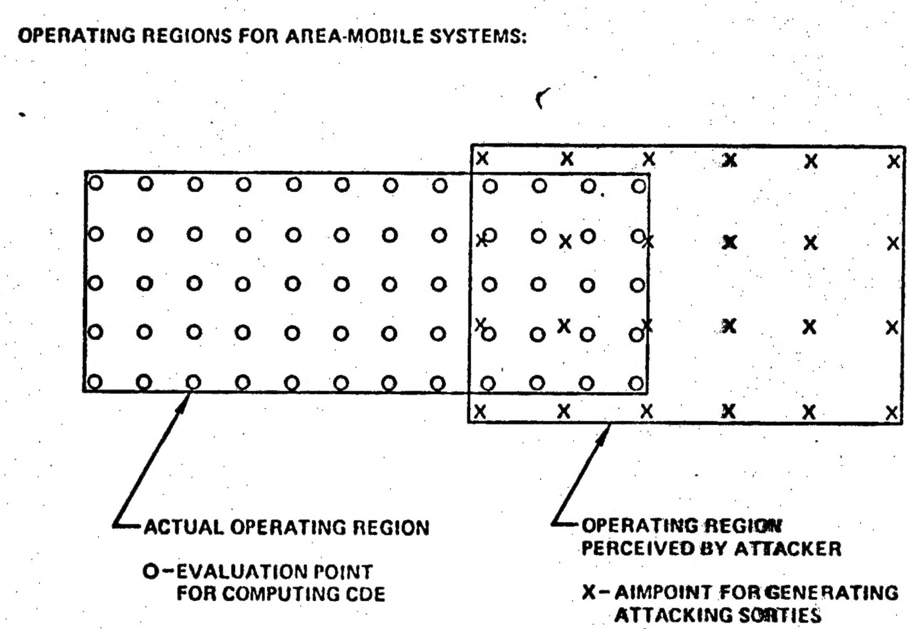


Figure 2 - Representation of Actual and Perceived Operating Regions.

1.3 Accessibility Subsystem

The Accessibility subsystem is a stand-alone system that produces data required by the Allocation and Assignment subsystems to model constraints on the ability of a missile to

deliver weapons to targets. Results are stored on the STRAT MISSILER data base. The user needs to execute Accessibility only when he defines a new missile configuration or bases an existing configuration at a new wing or patrol area location. Accessibility also produces an output report summarizing range and footprint performance characteristics of all defined force elements.

STRAT MISSILER modeling algorithms are sufficiently general to treat a broad spectrum of ballistic missile systems, including single Reentry Vehicle (RV) , Multiple Reentry Vehicle (MRV) and Multiple Independently-targetable Reentry Vehicle (MIRV) missile. This model does not simulate cruise missiles or maneuvering reentry vehicles, but does model MIRV configurations deploying two different types of reentry vehicle. The booster models will treat systems employing as many as four booster stages, although no currently operational system uses more than three stages.

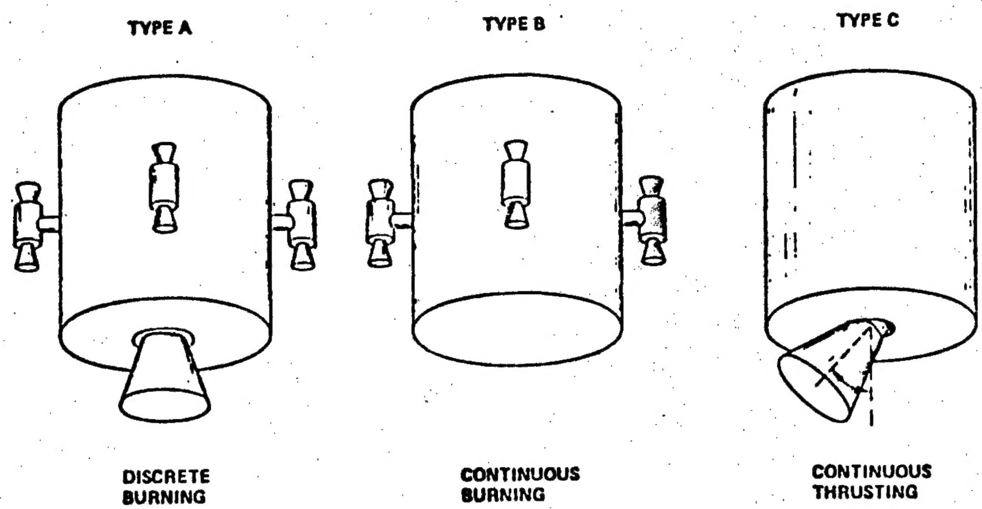


Figure 3 - PBV Propulsion Models

Figure 3 illustrates the three types of post-boost vehicle (PBV) propulsion systems modeled. The type A PBV uses separate thrust systems for target acquisition and rotation maneuvers. The engines are actuated at the command of the guidance system

and the PBV has the ability to coast without consuming fuel. The type B PBV uses a single thrust system to perform both target acquisition and rotation maneuvers. The engines burn fuel continuously once the system has been ignited. This type of PBV performs a coast maneuver only by activating opposing pairs of thrusters, and hence consumes fuel even during coasts. The type C PBV differs from the others in that it does not have a coast capability; a single gimbaled engine provides thrust for both target acquisition and attitude control, so this type of PBV continues to accelerate even during rotation maneuvers.

STRAT MISSILER provides two options which allow the analyst to develop data for advanced or general missile systems: a detailed model (up to 105 parameters) that uses simulation techniques; and an aggregated model (15 parameters) that processes overall capabilities. As an option, Accessibility performs an automated calibration of modeling parameters to achieve specified capabilities. This feature aids the analyst in selecting appropriate values of modeling parameters for advanced systems. This subsystem also performs default calculations for a number of parameters, thereby reducing the input burden for cases in which modeling parameter values are not well defined.

1.4 Allocation Subsystem

The Allocation subsystem may be executed stand-alone or in conjunction with other STRAT MISSILER subsystems. It produces a distribution of weapons to aimpoints, satisfying constraints (e.g., range, numbers of weapons, critical targets, weapon mix, multiple hits, cross targeting, and penaids) while attempting to maximize either aimpoint coverage or total value points bought. Allocation (and Assignment) use an aimpoint representation of the target system. The aimpoint data base, which is created external to STRAT MISSILER, consists of primary-supp complexes; each complex contains a primary aimpoint and may contain as many as eight tiers of supplementary aimpoints. Each aimpoint tier is eligible only to specific weapon types, based on weapon effectiveness against the installations represented by the aimpoints. (See the glossary for definitions of terms such as primary-supp complex, eligibility, and hit).

Allocation treats missile-delivered weapons (modeling only range constraints on target accessibility) and aircraft-delivered weapons (without modeling any accessibility constraint) and accepts a large set of control options that permit the analyst to tailor the weapon distribution to the needs of an individual scenario. For example, the following are various options: only weapons with penetration aids be used against defended aimpoints; a specific mix of weapon types be used against a planner segment; or a specific planner segment

receive multiple hits.

The role of the Allocation subsystem within STRAT MISSILER is primarily aiding the user in defining a structure (weapon mix) for the plan to be generated. This module always tries first to maximize coverage of critical planner segments and then to maximize either total coverage or value points bought. In addition, the subsystem accepts a set of controls that may be specified as either requirements or goals. If necessary, Allocation will sacrifice coverage of non-critical planner segments to satisfy a requirement, but it will satisfy a goal only to the extent possible without sacrificing total coverage or value bought.

These features coupled with the global allocation technique enable one to try various planning guidelines (planner segment organizations; designations of critical planner segments; controls on multiple hits, cross-targeting, and weapon mix) and determine the potential losses in global effectiveness before proceeding to generate a timed laydown. Allocation itself does not compute CDE or expected value destroyed(EVD), but the Analysis subsystem may be employed to make these evaluations of Allocation results.

1.5 Assignment Subsystem

The Assignment subsystem is the most detailed of the STRAT MISSILER plan generating elements. It forms sorties connecting individual reentry vehicles with aimpoints (Assignment does not treat aircraft-delivered weapons). Accessibility tests are performed to verify that each sortie is within the missile capability by checking for compliance with trajectory-shaping constraints, PBV fuel capacity, and mission time limits.

This subsystem treats single-RV, MRV, and MIRV configurations of ballistic missile systems. Assignment forms a non-MIRV or MRV sortie by associating a sortie with a single eligible aimpoint that is within the missile system's capabilities (The Analysis subsystem uses the MRV pattern radius to determine RV impact locations for calculating damage expectancy to the installations).

Missile MIRV configurations may carry either one or two types of RV. If the configuration carries one RV type, then the software deploys at most one RV from a single missile to each aimpoint in the sortie. A MIRV configuration that deploys two RV types is restricted to carry the same number of each type but may release either one or two RVs at each deployment station. If only one RV is released at each station, the model alternates between the two RV types. If two RVs are released at each station, then one of each type is deployed.

Both fixed-site and mobile-based missiles may be assigned. Assignment tests the accessibility of a candidate sortie from each extreme point of the patrol area for a mobile-based system to verify that the sortie could be executed from any launch point. The output of this subsystem includes a list of accessible sorties; trajectory data such as time of flight, reentry angle, and back azimuth; and, for mobile-based missiles, the variations in the trajectory data caused by the uncertainty in launch location.

The most important assignment objective is obtaining complete coverage of those planner segments designated "critical" by the analyst. An auxiliary objective is to maximize either total coverage of aimpoints or value points bought, depending on the operating mode selected. Because of the complex accessibility constraints for MIRV missiles, Assignment does not employ linear programming methods, but uses decision-making algorithms based on experience with operational weapon application programs (Reference 10).

This subsystem assigns sorties sequentially, treating one configuration at a time in an order either defined by the user or determined by the program. For a given configuration, Assignment always forms candidate sorties in those portions of the target system for which accessibility is most constrained. This procedure, which may be thought of as working in from the periphery of the target system toward the center, tends to maximize the number of sorties that can be formed because it preserves as long as possible those dense target areas where MIRV set formation is relatively easy.

Considering critical aimpoints before non-critical aimpoints, Assignment selects an aimpoint that is within the range capability of the force element being considered but is in a sparse target region. This aimpoint provides a focal point for forming candidate sorties. The code then selects aimpoints in the vicinity of the focus, constructs an aimpoint sequence that tends to minimize the penalty in PBV fuel for acquiring crossrange targets, and tests sortie accessibility.

After forming sorties for all configurations, Assignment attempts to improve the global solution quality. First, all critical aimpoints are identified that have not been covered, and attempts to modify individual sorties by exchanging non-critical aimpoints for uncovered critical aimpoints. In the value mode, Assignment then tries to increase total value points bought by modifying sorties to exchange low-value non-critical aimpoints for uncovered high-value aimpoints. In the coverage mode, to improve performance against specified weapon mix goals, aimpoints are exchanged between sorties to meet weapon mix

goals.

As an option, Assignment will perform further modifications to reduce interactions among the sorties. Figure 4 shows two three-RV sorties that have potential fratricide interactions. It is possible that each sortie covers the other sortie, creating mutual fratricide that would degrade the launch schedule. Assignment attempts to reduce the number of potential mutual interactions using geometric techniques. This is accomplished by forming a convex hull for each set, identifying overlapping convex hulls, and attempting to exchange aimpoints between sets to eliminate the overlap. Figure 4b shows the resolved sorties that this technique would produce for the set geometry of Figure 4a. Additionally, sortie interactions are reduced in dense target regions by exchanging sorties between force elements, based on the back azimuths and flight times of the sorties.

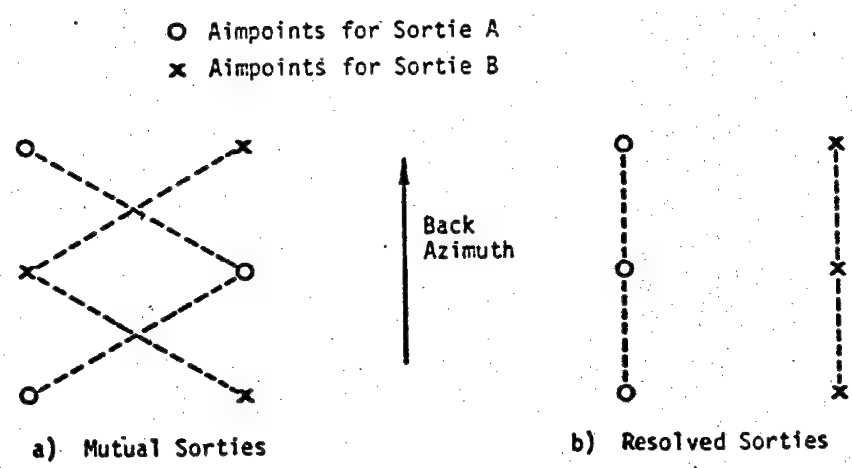


Figure 4 - Reduction of Sortie Interactions

Assignment accepts controls on the utilization of penetrations aids. The user may require that each missile deploy all of these penetration aids, regardless of the defended status of the aimpoints. Alternately, the user may require that penetration aids be deployed only when attacking defended

aimpoints; in this case this subsystem may suppress deployment of some of the penetration aids in order to achieve sortie accessibility.

In addition, Assignment accepts control options that constrain the sortie assignment in terms of country purity, option purity, cross-targeting requirements, and weapon mix against a planner segment. Figure 5 shows an aimpoint distribution that could be encountered during sortie formation. The focus aimpoint is located in a cluster of other aimpoints, but only a subset of these aimpoints is available for sortie formation if purity constraints have been imposed requiring all aimpoints in a MIRV sortie to belong to the same purity group. Given STRAT MISSILER MIRV configurations may deploy as many as 50 RVs, MIRV set formation for such configurations in a sparse target system can be quite difficult with various purity constraints invoked.

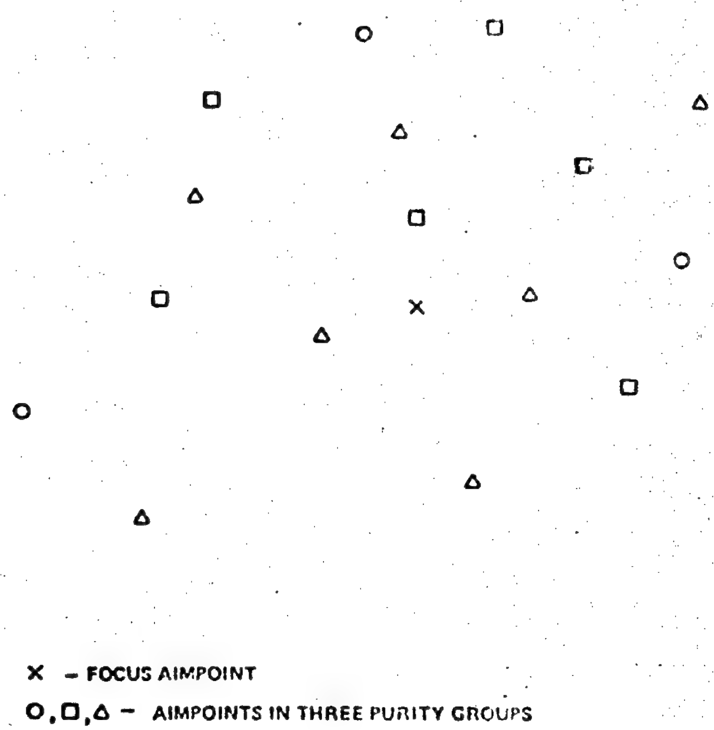


Figure 5 - Aimpoints for Set Formation

1.6 Scheduling Subsystem

The Scheduling subsystem accepts missile sorties, fratricide data, time-on-target uncertainties (TOTU), and controls to produce a launch schedule that satisfies constraints

on launch rate and probability of fratricide while attempting to minimize either the launch span or the impact span. The total scheduling problem may be organized into packages by defining target groups called scheduling planner segments and requesting that either the launch or impact span be minimized separately for the sorties attacking each planner segment.

The only procedure known to produce an optimal schedule is exhaustive enumeration and comparison of all possible schedules, which is not practical for a maximum-size STRAT MISSILER schedule of 3,000 missile sorties (Reference 23 gives a useful survey of current mathematical theories for the general scheduling problem). Therefore, STRAT MISSILER uses algorithms based on the operational practice of constructing a compact schedule that satisfies specified controls on fratricide and launch rate, treating sorties one at a time (References 11, 12, 13).

The first step in scheduling is constructing a sequence for considering the sorties, based on input priority specifications and potential fratricide interactions. The second step in scheduling is assigning a launch time to each sortie, considering the sorties in the sequence determined in the first step. Each sortie is assigned the best available launch time, taking into account the constraints imposed by interactions with the sorties that have already been scheduled. Figure 6 illustrates this process, which deals with launch slots.

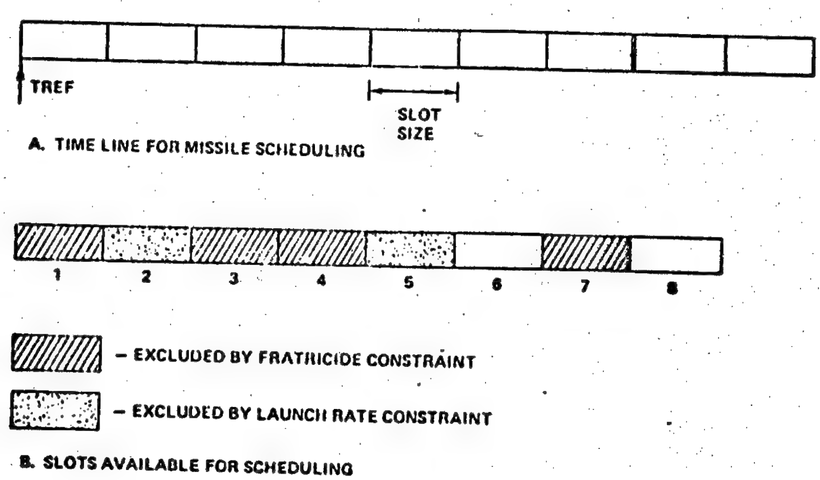
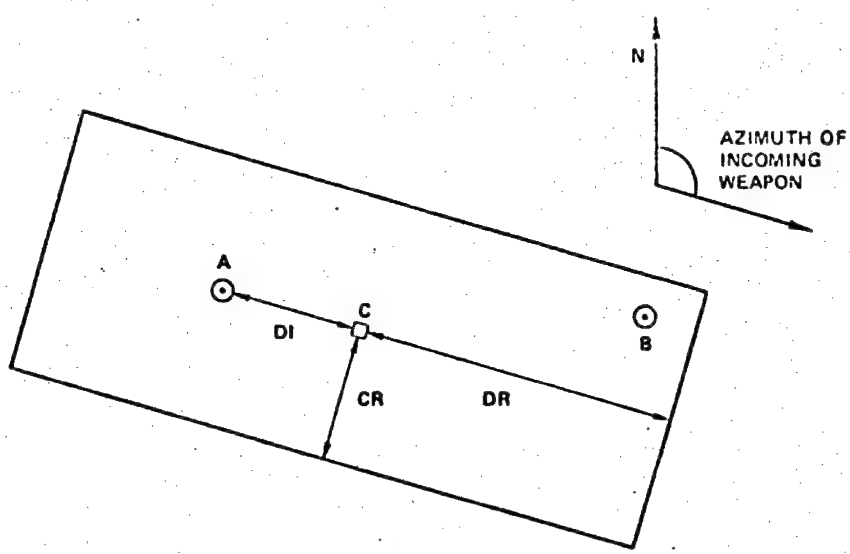


Figure 6 - Use of Launch Slots in Scheduling

The size of the launch slot indicates the uncertainty in launch time for the force element under consideration. Scheduling assigns a nominal launch time at the center of a particular slot, but the actual launch could occur at any time within the slot. As shown in Figure 6a, the time line for scheduling starts at a specified reference time (no launch event may occur earlier than this time) and is quantized in launch slots. Scheduling picks the best slot available for the sortie under consideration, requiring that the entire slot satisfy the upper bound on fratricide and launch rate. The choice of a slot becomes increasingly constrained as more sorties are scheduled. In the example shown in Figure 6b, if the objective is to minimize the launch span, then the best slot available for the sortie under consideration is number 6, since the earlier slots are excluded.

Scheduling determines whether a candidate launch slot for a sortie is fratricide-excluded by computing the time interval (exclusion period) during which the aimpoint(s) for the sortie is covered by fratricide exclusions caused by other weapons. The fratricide model is fast-running because Scheduling examines a large number of these potential RV interactions.



A: AIMPOINT FOR WEAPON CREATING NUCLEAR ENVIRONMENT
B: AIMPOINT FOR POTENTIALLY COVERED WEAPON
C: CENTER OF EXCLUSION REGION AT TIME t
DI: DISPLACEMENT OF CENTER AT TIME t
DR: HALF-LENGTH DIMENSION AT TIME t
CR: HALF-WIDTH DIMENSION AT TIME t

Figure 7 - Dynamic Exclusion Model for Fratricide

Fratricide exclusion regions are modeled as time-dependent geometric shapes on the surface of the earth, obtained from the

data base for the RV types, height of burst, and reentry angle under consideration. The interpretation of this data is an RV hitting an aimpoint at a time such that the aimpoint lies inside the region would have had to fly through a lethal nuclear environment and thereby be destroyed by fratricide. As shown in Figure 7 at a particular time for a rectangular exclusion region, the model parameters are the location of the center of the exclusion region, the displacement of the center from the aimpoint for the weapon creating the nuclear environment, and the dimensions of the exclusion region.

Scheduling determines the orientation of the exclusion region using the back-azimuth of the sortie attacking aimpoint B, and computes the exclusion period as the time interval during which aimpoint B is contained inside the exclusion region from aimpoint A. In general, there may be additional exclusion periods caused by other sorties attacking nearby aimpoints. Reference 22 describes the exclusion region model for fratricide in detail, and provides very helpful discussions of nuclear environments, system responses, and modeling uncertainties.

1.7 Analysis Subsystem

The Analysis subsystem can process output from any of the plan-generation subsystems (Allocation, Assignment, Scheduling) by performing a group of assessment functions to evaluate the effectiveness of a postured missile force. Four sources of weapon attrition are considered: prelaunch attrition, loss during booster egress (flyout), interception by defenses, and fratricide in the terminal area. The prelaunch and flyout evaluations use counterforce sorties developed in a previously executed plan of an attacker. Analysis then computes the probability of arrival for each RV, target coverage, and CDE against an installation target base. Additionally, a set of special MOEs such as counter-military potential are computed taking into account attrition and reliability factors. Analysis also provides a parametric mode in which sets of modeling parameters may be varied to perform sensitivity studies.

This subsystem does not perform a discrete-event simulation, but uses expected value calculations to measure the effectiveness of a missile forces in performing a strategic plan. The most important measure is the calculation of CDE against the installation target system, which accounts for target hardness and location, weapon, yield, height of burst, accuracy, and probability of arrival. STRAT MISSILER models missile probability of arrival in terms of the factors shown in figure 8.

Five distinct contributions to missile reliability are

treated using values which can be supplied. Probability of communication models the reliability of generating and transmitting an emergency action message that is received and executed by the launch control center (Values for this parameter can be obtained using AF/SA models that treat command, control, and communications systems). The other reliability factors treat various missile subsystems.

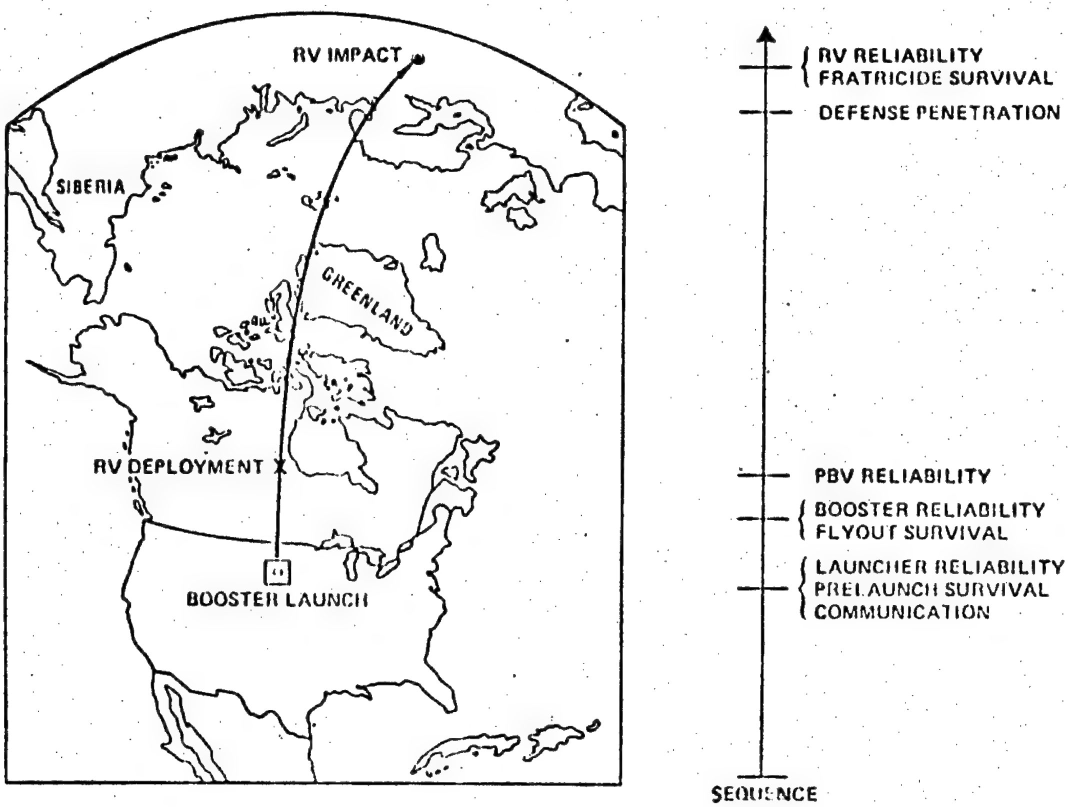
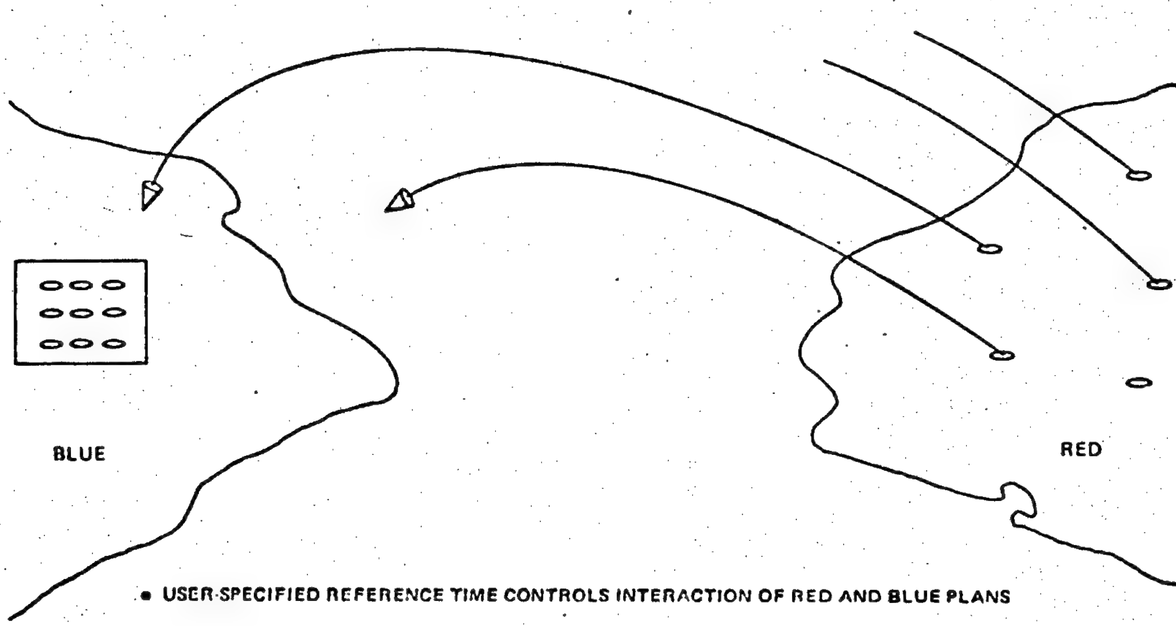


Figure 8 - PA Factor of a Missile Sortie

Figure 8 also lists the four attrition factors treated by STRAT MISSILER. In computing probability of arrival for each RV, STRAT MISSILER will either use values supplied by the analyst or will compute values for the factors selected. This subsystem models the survival of prelaunch and flyout attacks using counterforce sorties of the opposing plan, as indicated schematically in Figure 9 treating one side at a time.

Red is the side initiating the exchange and Blue is the side responding. In evaluating the damage expectancy achieved by the Blue response, Analysis uses the Red counterforce sorties

to determine the reduced probability of arrival for the Blue weapons. The interaction between the two plans is controlled by the analyst, who specifies a reference time that determines when the Blue launch schedule starts with respect to the Red impact schedule. In addition, launch delays may be specified for individual Blue force elements. This process may be extended to treat multiple exchanges.



- USER-SPECIFIED REFERENCE TIME CONTROLS INTERACTION OF RED AND BLUE PLANS
- RED COUNTER-FORCE SORTIES ARE USED TO EVALUATE BLUE SURVIVAL (PRELAUNCH, FLYOUT)
- USER CAN DELAY BLUE LAUNCH SCHEDULE FOR INDIVIDUAL FORCE ELEMENTS

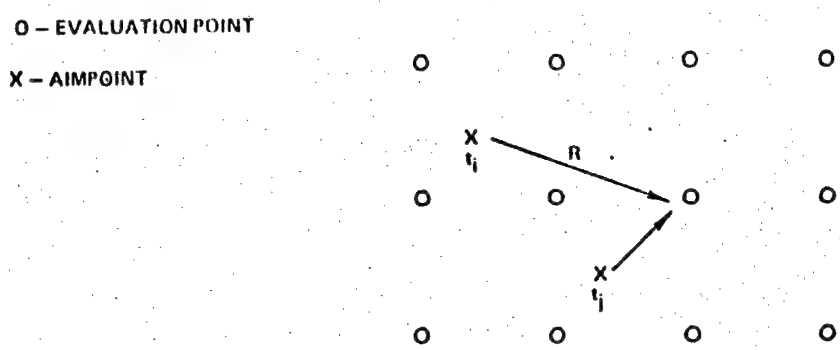
Figure 9 - Analysis Usage of Counterforce Sorties

1.7.1 Prelaunch Attrition

STRAT MISSILER's basic technique for computing prelaunch survivability (PLS) is to calculate the time-dependent CDE achieved by the attacking sorties against an opposing strategic missile force element. As indicated in figure 9, mobile systems are treated on an equal footing with fixed-site systems.

Computing PLS for area-mobile and air-mobile systems is somewhat more difficult than for fixed-site systems. Analysis uses the evaluation points produced by the Model Data Generation

subsystem to represent the actual operating region. Figure 10 illustrates the general approach.



- COMPUTE CDE (t_i), CDE (t_j) . . . FROM EACH WEAPON TO ALL EVALUATION POINTS

  OFFSET DISTANCE (R)

  YIELD, ACCURACY, HOB, PA

  NOMINAL VULNERABILITY

- COMPUTE AVERAGE $\overline{CDE}$ (t)

- COMPUTE PLS (t) = 1 – $\overline{CDE}$ (t)

Figure 10 - PLS Calculation for Mobile Bases

For each attacking RV, instead of computing CDE against a silo, Analysis compounds the damage achieved against each evaluation point in the vicinity. Basically the evaluation points are treated as though they were a set of installations representing the total base. Compound damage expectancy is computed as the Average CDE (ACDE) suffered by the evaluation points. For both fixed-site and mobile missiles, the prelaunch survivability of an individual missile is computed as (1-ACDE), using the value of ACDE at the scheduled time of launch for the missile. STRAT MISSILER does not use DIA methodology (Reference 4) in computing PLS for submarines, which are treated with functionalizations (Reference 19) of DNA data (Reference 6).

1.7.2 Flyout Attrition

The Analysis subsystem treats missile booster egress through a nuclear environment (flyout) using exclusion region data obtained from the DMS data base for the booster type, RV type, and RV height of burst under consideration. Figure 11 shows the geometric shapes used in the flyout exclusion model. The exclusion model represents the envelope caused by all lethal environments, so the three shapes shown in Figure 11 may be associated with different nuclear environments, depending on missile system vulnerabilities.

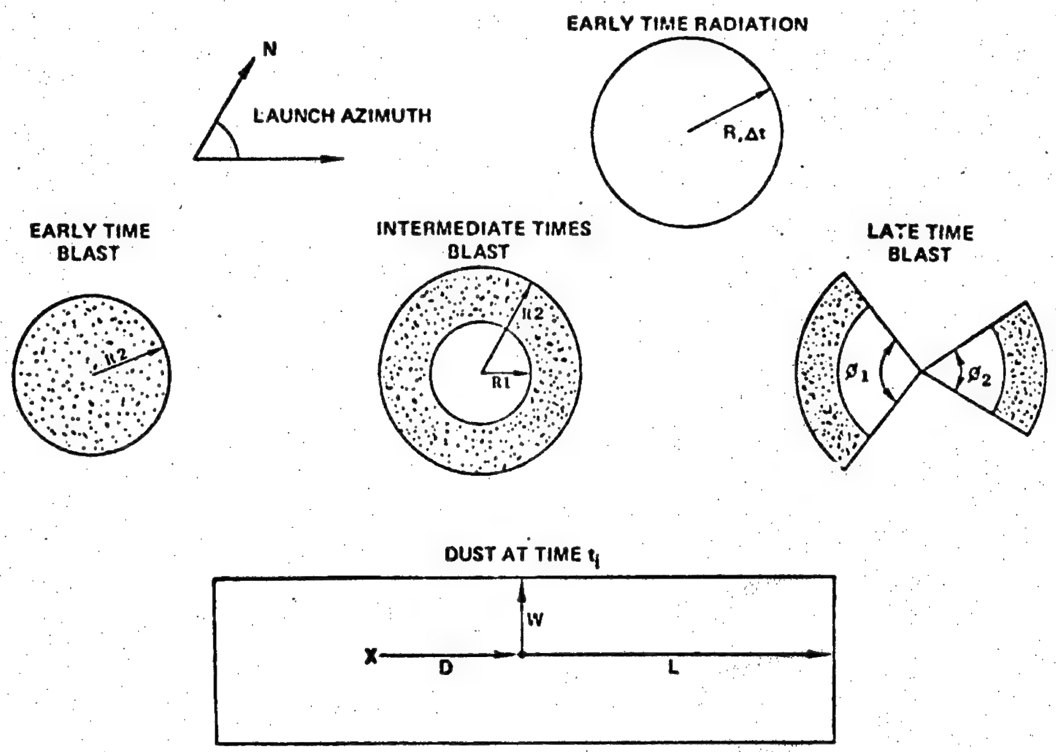


Figure 11 - Exclusion Regions for Flyout

The early-time model typically corresponds to radiation or EMP exclusions. The second model can include radiation exclusions, but it is primarily intended to treat effects caused by the blast environment. The shape of the blast exclusion region becomes more complicated at intermediate times because of the difference between the flyout speed of the missile and the propagation speed of the environment; by the time a missile

launched from the center intercepts the blast front the environment may have decayed to non-lethal levels. At late times the exclusion can degenerate even further, reflecting differences in system vulnerability to longitudinal and lateral blast effects. The third model treats persistent exclusions, such as those caused by the dust environment; this model has the same form as the one used by Scheduling in treating RV fratricide.

1.7.3 Defense Attrition

Attrition caused by defense interception of incoming RVs is modelled using a probabilistic treatment that includes the probability of site survival, the probability of acquisition (which accounts for detection, tracking, and identification), the probability of interception (which accounts for tracking, interception, and kill), and the number of interceptors.

The defense sites are contained on the aimpoint data base, and at user option Analysis computes the time-dependent probability of site survival based on the weapons attacking each site. For each RV attacking a defended aimpoint, STRAT MISSILER identifies the sites covering that aimpoint based on the geographic coverage provided by each defense site. Using rules based on the site's number of interceptors, probability of survival, and probability of acquisition, the program resolves the overlapping defense coverage by assigning the RV to one of the sites and decrementing that site's stock of interceptors. The probability that the RV is destroyed by the defense is computed as the product of the probabilities of site survival, RV acquisition, and RV interception.

The probability of acquisition and interception are modeled as configuration-dependent parameters, thereby allowing the analyst to distinguish between missile configurations. The Analysis subsystem also accounts for sortie-specific use of penetration aids by modifying the probabilities to account for partial deployment of penetration aids. Furthermore, site-specific values for the probabilities of acquisition and interception are computed using an exponential model to account for saturation effects.

1.7.4 Fratricide Attrition

The Analysis subsystem treats fratricide using the same models employed by the Scheduling subsystem, except for simplifications permitted by the fact that Analysis receives impact times for all of the RVs. Fratricide losses are calculated more accurately in Analysis than Scheduling, which is primarily concerned with avoiding fratricide. In particular, analysis models weapon probability of arrival while Scheduling

makes the conservative assumption that all weapons arrive. Including the fratricide model in Analysis enables the analyst to examine the fratricide implications of situations not treated by Scheduling. There are four principal situations of potential interest to the analyst:

1) The launch schedule perturbed by specifying a delay time for each force element which may lead to fratricide interactions;

2) The total launch schedule perturbed by changing each launch time by an amount chosen at random, thereby testing a "random scheduling" strategy;

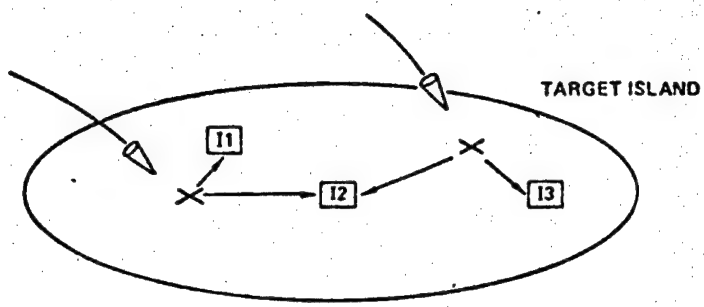
3) Time on Target Uncertainty (TOTU) values modified and used in computing the probability of fratricide, thereby testing the consequences of using values in Scheduling that are too liberal or too conservative;

4) Fratricide losses for schedules that were generated without regard for fratricide may be analyzed also.

1.7.5 Damage Calculations

STRAT MISSILER compounds the reliability and attrition factors into an RV-dependent probability of arrival using input and/or program computed values for the attrition factors. The Analysis subsystem then computes the CDE achieved by the RVs against the target systems: installations (both point and area), P-95 targets, rural population cells, and aimpoints.

Figure 12 illustrates the damage calculations for installations. All installations within a single target island are treated at one time, since it is assumed that a weapon directed to one target island cannot damage an installation in another target island. Weapons are treated in the order of impact, computing the damage expectancy to all installations using the weapon probability of arrival, yield, accuracy, and height of burst. Calculations are based on standard DIA methodology. Damage calculations for the non-target installations in the target island may also be performed.



- DIA METHODOLOGY
- INSTALLATION CHARACTERISTICS
  - HARDNESS (LETTER CODES L THROUGH U)
  - AREA, VALUE
  - DISTANCE FROM AIMPOINT
- WEAPON CHARACTERISTICS
  - YIELD, ACCURACY, HOB, PA
- COMPOUNDING ACCOUNTS FOR CORRELATIONS IN PA

Figure 12 - Installation Damage Calculations

1.7.6 Measure of Effectiveness

Analysis computes a set of static measures of effectiveness (MOE) to aid the user in comparing STRAT MISSILER results with those obtained in other studies. Each MOE is computed for the total force and then decremented to account for the residual forces as each reliability and survivability factor is taken into account in the order shown in figure 8. The MOE's are: number of missiles, number of RVs, throwweight, megatonnage, equivalent megatonnage, adjusted equivalent megatonnage, hard target potential, and counter military potential.

GLOSSARY OF TERMS AND ABBREVIATIONS

Accessibility - The capability of a missile to deliver weapons to targets. The Allocation subsystem models accessibility as a constraint on the range from the launch point to the target. The Assignment subsystem models accessibility as a constraint on the fuel available to acquire targets while obeying constraints on trajectory parameters such as reentry angle and interobject spacing.

Accuracy - A missile system's capability to deliver an RV near an aimpoint. Quantitatively, accuracy is usually specified in terms of CEP.

Aimpoint - The location of a ground zero selected for a weapon delivery. The location may be coincident with that of an installation or may be adjacent to a group of installations. Aimpoints are chosen based on the desired level of destruction, hardness of the installation(s), weapon type, weapon system accuracy and height of burst.

Allocation - The process of distributing strategic weapons to an aimpoint target system, while taking into account weapon system capabilities (such as missile range capability) and planner objectives (such as cross-targeting).

Analysis - STRAT MISSILER subsystem that evaluates attrition factors, computes CDE and EVD, and calculates measures of effectiveness.

Area destruction - The ground surrounding a nuclear weapon detonation that is subject to at least specified level of a particular nuclear weapon effect. The effect type, usually peak overpressure, and the effect level (usually expressed in psi for peak overpressure) are chosen based on the characteristics of targets of interest adjacent to the detonation. It is sometimes expressed in units of megaton-equivalent (MTE).

Assignment - The process of associating specific reentry vehicles with specific aimpoints while obeying detailed accessibility constraints and trying to satisfy planner goals for weapon mix and cross-targeting.

Attack option - A two-digit integer assigned by the user to each target, based on characteristics such as category, target type, and time urgency. Attack option is a convenient key for identifying sorties to be withheld from execution; for example, in some scenarios it might be desirable to withhold sorties attacking government control centers.

Attrition factor - Probability that missile or weapon is

destroyed by enemy action or by fratricide before completing its intended mission.

Back azimuth - The angle between two planes intersecting at the RV impact point; one plane contains the trajectory and the other plane contains the meridian. Back azimuth is an inertial parameter similar to firing azimuth, except that it points "back" from the impact point to the launch point.

Ballistic coefficient - A design parameter used in performance analysis of objects moving through the atmosphere. In missile terminology, it is usually called beta and is defined as weight/(area*drag coefficient), where the drag coefficient is usually taken to be the asymptotic hypersonic value.

Booster - Initial stages of a missile providing thrust before releasing the RV or post-boost vehicle.

Booster range (minimum and maximum) - Capability parameters used to calibrate STRAT MISSILER simulation models. Maximum (minimum) range value corresponds to range measured for a north-firing trajectory (ie., earth rotation and launch latitude do not affect range) with reentry angle that maximizes (minimizes) range from the launch point to the impact point corresponding to the burnout state vector. The launch point is assumed to be at sea level. (Typical results for a modern MIRV system are that increasing the launch elevation by 1,000 ft increases the maximum range capability by about 10 nmi).

Burst point - Latitude, longitude and height above the earth's surface specifying the detonation location of a nuclear weapon targeted for an installation or group of installations.

Burst type - An option code for a particular weapon system that denotes the weapon height of burst. The burst types treated by STRAT MISSILER are surface (S), low-altitude (L), air (A), high-altitude (H), and below-surface (D, for depth of burst, only for attacks on submarine-based missile systems). The burst altitudes corresponding to these codes depend on the characteristics of the weapon system.

Candidate sortie - Tentative assignment of weapons on a single booster to specific targets; a candidate sortie might not satisfy accessibility constraints.

Category - A five-digit integer assigned by the user to each target, based on its characteristics. STRAT MISSILER uses the category number as a sort key for organizing output reports; at user option, targets are aggregated using the user-selected number of leading digits in the category number.

CEP - The abbreviation is usually defined as standing for "circular error probable", but "circle of equal probability" is more descriptive. CEP is a measure of weapon system accuracy which is defined at that distance from an aimpoint within which a weapon or RV has .5 probability of falling. Therefore it is equally probable that the RV will land inside or outside a circle whose radius is equal to CEP.

Chaff - A device used to protect incoming RVs exo-atmospherically by confusing defensive radar and thereby aiding penetration of defenses. Chaff consists of thin, narrow metallic strips deployed from the PBV at appropriate altitudes. The strips are intended to provide strong radar targets, thus giving the defense a target discrimination problem and degrading its ability to destroy the incoming RV.

Coast - Period during which there is no net thrust to cause vehicle acceleration; if drag is insignificant, then there is virtually no change in sensed velocity during a coast maneuver.

Collateral damage - Damage inflicted on installations adjacent to a weapon aimpoint. These installations are not installations for which the aimpoint was created. They may be military or non-military (e.g., economic recovery or urban-industrial) installations. The Analysis subsystem assesses collateral damage by computing damage to installations designated as non-target on the installation data base.

Compound damage expectancy (CDE) - Damage expectancy resulting from multiple weapons against a signal installation. Damage contributions from successive weapons are computed based on the current probability that the target is undamaged. CDE calculations account for correlation effects in arrival probability components, such as two weapons from the same booster affecting a single installation.

Configuration - Unique missile payload combination of weapons and penetration aids (e.g., Minuteman II PA, Minuteman III B3, Poseidon C3PA).

Constraint - A limitation that must be obeyed by the STRAT MISSILER plan generation subsystems. For example, Allocation and Assignment must obey constraints on missile accessibility, weapon eligibility, and the number of available weapons.

Convex hull - In set theory, the smallest convex set that contains all of the points of the set. A convex curve in a plane is cut at just two points by any straight line that cuts the curve. Therefore, in STRAT MISSILER usage, the convex hull of a MIRV aimpoint set is the smallest convex polygon that includes all aimpoints.

Country code - A two-character Hollerith identifier assigned by the user to each target, based on its geographic location.

Cover - Potential fratricide interaction between two missile sorties; the sortie that could cause fratricide is said to cover the other sortie. Covers are identified by measuring the geographic proximity of aimpoints attacked by the sorties, taking into account the pair-wise fratricide characteristics of the RV types. Whether fratricide actually occurs depends on the relative impact times of the RVs in the sorties. The Scheduling subsystem uses cover information to determine a favorable sequence for assigning sortie launch times; if sortie A covers sortie B, then it is usually desirable to schedule sortie B first because it cannot delay Sortie A, but it could be delayed if Sortie A were scheduled first. The term is also used for potential flyout interactions between launching missiles and locally detonating RVs. The Analysis subsystem uses cover information to determine probability of flyout survival for missiles launching under enemy attack.

Coverage - Measure of effectiveness for Allocation and Assignment. Coverage is computed as the percentage of primary-supp complexes receiving at least one hit.

Coverage_mode - An operational mode of the Allocation and Assignment subsystems. When operating in this mode, each subsystem distributes or assigns weapons to aimpoints while attempting to maximize the number of primary-supp complexes receiving at least one hit, disregarding differences in aimpoint value.

Cover chain - A list of sorties that are linked by cover relationships. for example, sorties A, B, and C would form a cover chain if A covers B and B covers C. Cover chains can be extremely long and complex, depending on the aimpoint density, MIRV set composition, and RV fratricide characteristics. The Scheduling subsystem identifies cover chains as one step in determining the sortie sequence for scheduling; in general, the sequence that minimizes delays caused by fratricide starts at the bottom of the chain and proceeds up the chain. In the example above, the scheduling sequence would be: C, B, A.

Cover level - A numeric index assigned to each sortie by the Scheduling subsystem, based on cover relationships. The cover level is zero for a sortie that does not cover any other sortie. Otherwise, the cover level of Sortie A is equal to the highest cover level of any sortie covered by Sortie A, incremented by one. For example, if sortie A covers only sorties whose cover level is zero, then the cover level of Sortie A is one.

Critical targets - Within a set of strategic objectives, those targets whose destruction has the highest priority. This priority may require target destruction at the earliest possible time and it may also require high confidence that a specific level of damage will be attained. In STRAT MISSILER the user may designate individual planner segments as containing only critical targets.

Crossrange - Direction of constant inertial range from missile launch point to RV impact point. For Accessibility calculations, STRAT MISSILER defines the crossrange direction by forming a vector that is orthogonal to the downrange direction and that lies in a plane tangent to the earth at the RV impact point. The model's sign convention is that the crossrange direction (y-axis) forms a right-handed vector triad with the local vertical (z-axis) and the downrange direction (x-axis). Note that the crossrange direction is a function of trajectory time of flight because of earth rotation. This sign convention is important for interpreting Accessibility footprint results because crossrange capability is not necessarily symmetric about the downrange axis; one direction or the other is usually favored by earth-rotation effects. The sign convention is not important for Scheduling and analysis in treating fratricide exclusion regions because they are assumed to be equally large in the positive and negative crossrange directions.

Cross-targeting - Process of attempting to distribute or assign weapons to specific groupings of targets, such as country or planner segments, such that these groupings are not attacked predominantly by a single missile system or force element. Multiple-hit aimpoints may also be cross-targeted.

Damage expectancy (DE) - For a single weapon against a single installation, DE is the single shot damage probability (PD) multiplied by that weapon's probability of arrival (PA).

Decoy - Deployable object that has no destructive capability, but is difficult for defense sensors to distinguish from an RV.

Defense penetration - Successful completion of an RV trajectory down to its designated burst point, taking into account interactions with defense systems such as sensors and interceptors.

Dense target complex - A group of geographically-clustered aimpoints that require special treatment; these aimpoints may belong to different target islands, but are sufficiently close that fratricide interactions may be important. For example, a dense target complex could contain all of the silos in a missile wing as well as launch control centers and adjacent targets such

as airfields and controls. At user option, the Assignment subsystem applies special algorithms to resolve potential interactions between sorties assigned to the same dense target complex. The analysis subsystem relies on the dense target complex ID as a sort key to collect the targets needed for calculating flyout survivabilities.

Deployable object - Object released or ejected from missile during flight, e.g., RV, chaff, shroud.

Deployment - Maneuver that results in separation of RV from missile. Depending on system design, the PBV of a MIRV system may perform a complex series of operations to make vernier adjustments in velocity and to orient the RV for zero angle of attack at reentry. In general there are two types of deployment mechanization: passive deployment simply releases the RV from the PBV without imparting any velocity to the RV; active deployment changes the RV velocity by using a ramp, spring, or similar mechanism. STRAT MISSILER restricts its treatment of active deployment to cases for which the added velocity changes the time of flight but not the impact point. (That is, the additional velocity is along the range-insensitive axis.

Deployment sequence - A set of numbers representing which chaff clouds (in order of deployment) cover RVs. Thus a 2, 5, 8 deployment sequence means there are RVs in the 2nd, 5th, and 8th chaff clouds.

Deployment station - Segment of missile mission during which one or more reentry vehicles are deployed. In STRAT MISSILER usage, the number of deployment stations for a missile configuration equals the number of aimpoints that can be targeted independently. Each deployment station for a MIRV missile corresponds to the PBV state vector (time, position, velocity) at the moment of RV release. STRAT MISSILER treats MIRV configurations that release as many as two RVs at a single station; in these cases, the RVs are released at the same time. If the RVs are of different types, then the velocity component along the Range Insensitive Direction (RID) of the second RV may be adjusted by a specified amount, thereby achieving a separation in Rv impact times. (Impact times are also affected by the ballistic coefficients.)

DGZ - Designated Ground Zero; aimpoint for installation or group of installations.

DMS - The Data Management System of the Advanced Penetration Model (References 8 and 9), STRAT MISSILER uses DMS for all interactions with the data base.

Downrange - Direction of increasing inertial range from missile

launch point to RV impact point. The downrange direction is usually defined by projecting the RV velocity vector at impact onto a plane that is tangent to the earth at the impact point. STRAT MISSILER approximates this definition by using the line determined by the intersection of the tangent plane and the plane containing these points: center of the earth, missile launch point, and RV impact point. Downrange is then the direction of increasing range and uprange is the direction of decreasing range. Note that the downrange direction is a function of trajectory time of flight because of earth rotation. See also crossrange.

Dust cloud - An all-inclusive term for the turbulent mixture of hot gases, smoke, dust, and other particulate matter from the weapon itself and form the environment, that is carried aloft in conjunction with the rising fireball produced by the detonation of a nuclear weapon. The cloud can persist for many minutes after a nuclear explosion. The dust cloud decreases in particulate density with time as the cloud increases in volume and as larger particulates drop out.

Electromagnetic pulse (EMP) - The time varying electromagnetic radiation that results from a nuclear weapon detonation.

Eligibility - A constraint obeyed while assigning weapons to aimpoints. Aimpoints are constructed using nominal weapon characteristics (yield, accuracy, and height of burst); only weapons whose actual characteristics are such that the weapons achieve satisfactory damage against the installations are eligible for assignment. Eligibility is therefore determined during the process of constructing aimpoints. In STRAT MISSILER, each aimpoint has an associated list of eligible weapon types. Allocation and Assignment will not match a weapon with an aimpoint unless the weapon type is included in the list of types eligible for that aimpoint. A limitation on the aimpoint-generation process is that all supplementary aimpoints in a single tier of a primary-supp complex must have the same list of eligible weapon types.

Equivalent radius - Modeling parameter for area targets; obtained by analysis subsystem from DMS data base and used in computing compound damage expectancy and expected value destroyed. STRAT MISSILER performs area damage calculations for aimpoints, installations, P-95 targets, and rural cells. Except for rural cells, (which have uniform value distribution), STRAT MISSILER assumes a circular normal value distribution for all area targets. The program then performs damage calculations by first computing the joint distribution of the target value distribution and the weapon impact distribution and second computing the damage probability as if for a point target. Reference 5 explains this method.

Evaluation point - One element in a grid of geographic locations that covers the actual operating region of a base for mobile missiles. The user specifies the separation between evaluation points in the grid At user option, the Model Data generation subsystem creates the grid of evaluation points. The analysis subsystem uses the evaluation points for computing the survival of mobile-based missiles under prelaunch or flyout attacks.

Expected value destroyed (EVD) - The number of value points bought (destroyed) by detonation of nuclear weapons at or near an installation or group of installations. It is computed for each installation by compounding the damage expectancy achieved by all weapons and multiplying by the installation value.

Firing azimuth - The angle between two planes intersecting at the launch site; one plane contains the missile trajectory and the other plane contains the meridian. Firing azimuth differs from sighting azimuth because of earth rotation. The STRAT MISSILER sign convention is that azimuth is a positive quantity varying clockwise between zero and 360 degrees.

Flyout exclusion region - A time varying two-dimensional region fixed spatially relative to a nuclear weapon aimpoint. Missiles whose launch times and locations lie within the exclusion region are assumed to incur sufficient damage to be killed.

Flyout survivability - The ability of a missile to survive, after launch, exposure to environments created by the detonation of nuclear weapons.

Focus DGZ - The DGZ selected by the assignment algorithm as a starting point for selecting a MIRV target set.

Footprint - A measure of the RV deployment capability of a MIRV missile system; footprint is defined in terms of uprange, downrange, and crossrange excursion limits. In STRAT MISSILER usage, footprint dimensions are measured while deploying objects to evenly-spaced targets.

Force - See missile system and total force.

Force element - Group of missiles of same system and configuration located at a single base (squadron, wing, or patrol area).

Fratricide - Weapon kill from a nearby friendly weapon explosion. Refers to the fact that the results of nuclear explosion (blast, nuclear radiations, and nuclear cloud particulates) make it difficult or impossible to deliver a reentry vehicle to or near the same point soon after an earlier

weapon has arrived and detonated.

Fratricide exclusion region - A time-varying, two-dimensional region fixed spatially relative to a nuclear weapon aimpoint. RVs on trajectories terminating at aimpoints inside the exclusion region are assumed to incur sufficient damage to be killed before they can detonate.

Fratricide footprint - See fratricide exclusion region.

Goal - An optional user input to the Allocation and Assignment subsystems that controls a weapon distribution for the specified planner segment. Examples of control options that may be specified as goals are weapon mix and cross-targeting. Allocation and assignment attempt to satisfy goals, but not at the expense of the objective (coverage or value), coverage of critical planner segments, and other control options specified as requirements.

H-supp - High-yield supplementary aimpoint.

Hardness - A measure of the ability of a system to withstand exposure to one or more of the various effects of nuclear weapon detonations.

Height of burst (HOB) - Height above the earth's surface at which a nuclear weapon detonation occurs. The aimpoint data base includes an HOB burst type (surface, air, or high altitude) for each weapon system eligible for an aimpoint. The burst type is used by Scheduling to select the appropriate fratricide exclusion region; it is also used (at user option) by Analysis to select a default HOB, in feet, for damage calculations. The aimpoint data base includes an HOB value, in feet, for each weapon system eligible for an aimpoint. These weapon system HOB values may differ from the burst type default values. At user option, Analysis uses this HOB value for damage calculations.

Hit - In STRAT MISSILER usage, the unit of value for computing target coverage. Hit is defined by considering the installations underlying the aimpoint representation; in order to "cover" all of the installations corresponding to a primary-supp complex, one weapon must be assigned to the primary aimpoint or multiple weapons (one to each supplementary aimpoint) must be assigned to one of the low-yield supplementary tiers. Therefore, the relationship between the number of hits and the number of assigned weapons depends on which aimpoints were selected. Assigning one weapon to a high-yield supplementary (h-supp) aimpoint produces multiple hits, based on the number of primary aimpoints corresponding to the H-supp. Multiple hits against a single complex can be achieved by hitting the primary multiple times, by hitting multiple

supplementary tiers, or by hitting a combination.

Impact span - The time period, for a particular strategic plan, during which all RVs reach their targets.

Launch group - A specific aggregation of weapons related to each other by some aspect of their launch procedure. For land-based missiles it could be flight, squadron, wing, etc. For sea-based missiles it could be a single boat, a patrol area, etc. For aircraft-delivered weapons it could be a single aircraft, squadron, etc.

Launch patrol area - Operating region for a land area-mobile, sea-mobile, or air-mobile missile system. The missile system constantly patrols the entire region so that the missile location at the scheduled launch time cannot be predicted. Therefore, the sortie accessibility test must account for the corresponding uncertainty in trajectory time of flight.

Launch reference point - One of a set of geographic locations characterizing a launch patrol area. STRAT MISSILER accepts a set of as many as 10 points defining the perimeter of the patrol area; the Assignment subsystem tests the accessibility of a candidate sortie from each of the launch reference points. Allocation only tests the range from a single reference point; the user may supply the centroid of the patrol area, although it is more conservative to use one of the reference points farthest from the target system.

Launch site - Point from which a missile is launched.

Launch slot - Measure of the uncertainty in launch time for a strategic missile. Scheduling accepts a launch slot size for each force element, and accounts for slot size as a contribution to total time-on-target uncertainty in computing the probability of fratricide. Furthermore, Scheduling assigns launch times by finding the best available slot that satisfies user-specified constraints on launch rate and probability of fratricide. Therefore, Scheduling really assigns a launch slot rather than a specific launch time. The nominal launch time is at the center of the assigned slot. STRAT MISSILER requires that the launch slot size be non-zero and an integral multiple of six seconds.

Launch span - The time period, for a particular strategic plan, during which all missiles are launched.

Laydown - The complete set of sorties developed by the Assignment subsystem.

Lethality - A measure of the capability of a weapon to achieve a specified level of damage, due to overpressure against point

targets. Lethality (K) is defined by the expression

$$K = \frac{Y^{2/3}}{CEP^2}$$

where Y is weapon yield in MT and CEP is expressed in nautical miles.

MaRV - Maneuverable reentry vehicle; a MaRV has its own propulsion and control capability so that it can execute maneuvers after deployment from the missile. The objective of these maneuvers may be to increase the range for target acquisition, to improve accuracy by correcting for errors in deployment or reentry, or to evade interceptors in the terminal area and to confuse defense systems by disguising the identity of the RV's true target. STRAT MISSILER does not explicitly model these maneuvers, but the user can account for MaRV capabilities by supplying appropriate values for parameters such as accuracy and probability of defense interception.

Maximum range - For a non-MIRV missile system, the system maximum range is equal to the booster maximum range. For a MIRV missile system, maximum range is equal to the maximum booster range plus the PBV range extension, which is measured for an evenly-spaced sequence of aimpoints.

Measure of effectiveness (MOE) - Any of a group of parameters or figures of merit that can be used to assess the accomplishment of strategic objectives. Some measures of effectiveness are: compound damage expectancy for target or weapon groupings, target system coverage, expected value destroyed, and collateral damage.

Megaton equivalent - A unit of measure for area destruction from overpressure. It is defined as MTE = $Y^{2/3}$ where Y is weapon yield in megatons. MTE is used to compare area destruction capabilities of different yield weapons. See area destruction.

Minimum energy reentry angle - Reentry angle corresponding to minimum energy required to achieve a specified range; it is a function of firing azimuth because of earth rotation.

Minimum range - For a non-MIRV missile system, the system minimum range is equal to the booster minimum range. For a MIRV missile system, the minimum range may be further restricted by the minimum initial burn duration and the constraint on

interobject spacing. STRAT MISSILER measures the system minimum range while deploying all objects to a single aimpoint, and makes the simplifying assumption that a missile cannot target any aimpoint inside the booster minimum range.

MIRV - Multiple independently-targetable reentry vehicles deployed from a single missile.

Missile - Single booster with associated throwweight.

Missile system - Set of all missiles of same type that differ only in configuration (e.g., Minuteman II, Minuteman III, Poseidon C3P).

Mission time - Total time measured from launch, including thrust, coast, and free flight periods.

Model Data Generation (MDG) - STRAT MISSILER subsystem that computes aimpoints and evaluation points for mobile bases.

MRV - Multiple reentry vehicles deployed by a single missile, but not targeted independently. The STRAT MISSILER Assignment subsystem assigns an MRV missile to a single aimpoint.

MRV pattern radius - Although the Allocation and Assignment subsystems assign a MRV missile to a single aimpoint, thereby neglecting the actual RV impact pattern, the Model Data Generation and Analysis subsystems approximate the actual impact pattern by using a circle centered at the aimpoint. The size of the circle is determined by the MRV pattern radius, a configuration parameter input by the user. STRAT MISSILER distributes RV impact points uniformly on the circle.

Mutual - Missile sorties that cover each other are said to be mutual. Mutual sorties receive special consideration during scheduling because delays caused by fratricide cannot be eliminated, regardless of the sequence in which the sorties are considered.

Non-target - Any installation, group of installations, or urban-industrial area that is not included within the objectives of a strategic plan.

Objective - The Allocation and Assignment subsystems attempt to maximize the objective (coverage or value) specified by the user. The objective is used in determining how to distribute weapons to targets. The objective of the Scheduling subsystem is to minimize either the launch span or the impact span.

Option purity - A particular purity grouping based on a subset or stage of a strategic plan. The plan subset or stage has a

specific limited objective.

P-95 target - Area target representing population distribution. The distribution of population is assumed to be circular normal and the radius is that of the smallest circle containing 95% of the total population. Area targets whose value is based on urban/industrial facilities rather than population are sometimes referred to as R-95 targets. See References 4 and 5 for more detailed explanations. STRAT MISSILER computes damage to P-95 targets using the method discussed with equivalent radius.

Patrol area - A geographic region defining an on-stage area from which submarine-based missiles will be launched. Several patrol areas may be defined for a specific strategic plan.

Payload - Total weight of RVs on board a missile including warhead(s), container(s), and activating devices.

PBV range extension - In STRAT MISSILER usage, a parameter that characterizes the RV deployment capability of a PBV, PBV range extension is computed for a PBV mission that deploys all RVs but suppresses deployment of any penetration aids; the PBV deploys the first RV as soon as possible (see minimum initial burn duration) and deploys the other RVs to aimpoints that are equally spaced in the downrange direction. The other trajectory conditions are assumed to be the same as those used in measuring maximum booster range. PBV range extension is the surface range measured between the booster maximum range point and the farthest aimpoint in the equally-spaced set.

Penetration aid (pen-aid) - Object such as chaff deployed to confuse or saturate defense sensors.

Planner segment - An arbitrary grouping of aimpoints having some common target characteristic within the context of a strategic plan. Planner segment definitions may carry from subsystem to subsystem through a STRAT MISSILER execution, or may be redefined prior to execution of any subsystem. For any subsystem execution, however, an aimpoint may belong to at most one planner segment. See also Scheduling planner segment.

Post-boost vehicle (PBV) - Separate stage of a MIRV missile; used to increase system range capability, deploy reentry vehicles, and deploy penetration aids.

Preferred sortie - Identifier accepted by Scheduling subsystem; sorties identified as preferred in a Scheduling planner segment will not be delayed by interactions with other sorties within the planner segment that are not preferred. (A preferred sortie can be delayed only be interactions with other preferred sorties.) See also withhold sortie.

Prelaunch survivability (PLS) - The probability that a particular group of missiles will survive an attack up to their scheduled launch time.

Primary aimpoint - Principal aimpoint in a primary-supp complex that corresponds to a set of installations. Damage objectives against the installations can be achieved by assigning a single eligible weapon to the primary aimpoint. The first step in creating a tiered target system is usually selecting a set of primary aimpoints that cover all targets installations.

Primary-supp complex - Set of related aimpoints that correspond to a single set of installations. The complex consists of one primary aimpoint and a collection of supplementary aimpoints that are organized in tiers. A complex can contain no more than 9 tiers. Each tier in a complex is eligible to a unique group of specified weapon types. STRAT MISSILER assumes that the installations of concern can be destroyed by attacking either the primary aimpoint or all of the aimpoints in any one of the supplementary tiers. See also tiered target system, primary aimpoint, supplementary aimpoint, and hit.

Priority - A ranking that specifies the order in which objects will be treated. One STRAT MISSILER example is its use by the Assignment subsystem to designate the order in which missile configurations will be treated for set formation.

Probability of arrival (PA) - The probability that a missile configuration will deliver an RV that actually detonates (without considering accuracy) at its assigned aimpoint. PA is computed by compounding individual probabilities of success for each event required for a complete missile flight. These individual probabilities include prelaunch survivability, booster reliability, flyout survivability, probability of defense penetration, and the like.

Probability of damage (PD) - See single shot damage probability.

Probability of fratricide - The probability that a given RV will experience a kill by fratricide in attempting to reach its assigned target. Each fratricide exclusion region defines an area of sure fratricide kill (probability of fratricide is one); each of these areas is surrounded in space and time by another area whose probability of fratricide varies between one and zero.

Probability of survival (PS) - The probability that a system withstands a man-made hostile environment without suffering an abortive impairment of its ability to accomplish its designated mission. Purity constraint - a constraint that may be imposed

at user option during the assignment process requiring all reentry vehicles on a single mission to be assigned to aimpoints within the same purity group.

Purity group - A set of aimpoints having the same country code or attack option.

Range insensitive axis - Direction of thrusting that produces no change in earth-fixed impact point; also called range-insensitive direction (RID) and null range line (NRL).

Range sensitive axis - Direction of thrusting for which an increment of velocity produces the largest downrange displacement of the impact point, thereby increasing or decreasing the earth-fixed range from launch to impact. In STRAT MISSILER this axis is assumed to be perpendicular to the RID.

Reentry angle (RA) - Angle measured between local horizontal and RV velocity vector when RV descends to reference altitude, which for STRAT MISSILER is 300,000 ft. RV velocity is computed with respect to the atmosphere, which is assumed to be rotating with the earth.

Reentry vehicle (RV) - A missile subsystem consisting of a warhead, arming and fusing mechanisms and a structure to protect the warhead and other mechanisms during atmospheric descent.

Reliability - A measure of the proportion of equipment on station that performs correctly in an environment that does not include hostile acts. The term can be applied to any component of a weapon system and is frequently aggregated to the level of booster reliability, RV reliability and the like.

Requirement - An optional user input to the Allocation subsystem that controls weapon distribution for the specified planner segment. Examples of control options that may be specified as requirements include weapon mix, multiple hits, and cross-targeting. Allocation attempts to satisfy requirements while obeying constraints on accessibility, eligibility, and the number of weapons. Allocation will not sacrifice coverage of critical planner segments, but Allocation will sacrifice total coverage and value if necessary to satisfy requirements.

Restraint code - A "do not hit" indicator on the aimpoint data base; aimpoints with a non-zero restraint code are excluded from the allocation and assignment processes.

Scheduling - The process of assigning launch times to all

sorties in a strategic plan while observing operational constraints such as upper bounds on fratricide and launch rate, and while attempting to meet a scheduling objective such as minimizing the launch span.

<u>Scheduling planner segment</u> - User input control for the Scheduling subsystem. Scheduling planner segments define an organization of sorties based on the aimpoints they attack. The user may specify priority and objective for each planner segment. Launch times for sorties attacking a planner segment may not be delayed by conflicts with sorties attacking a lower-priority planner segment. A MIRV sortie can attack aimpoints in several planner segments; its launch time is assigned while treating the planner segment of highest priority.

<u>Set formation</u> - The Assignment subsystem process of defining a group of aimpoints that may be attacked with RVs from a single MIRV missile. Set formation must account for user-imposed constraints, such as purity, as well as sortie accessibility constraints.

<u>Single shot damage probability</u> - A measure of the destruction capability of a weapon system. Based on the DIA Physical Vulnerability System, it is the probability that a specified level of damage will be done to a single target by a single nuclear weapon. Computation of this probability includes effects or target hardness, weapon yield, weapon height of burst, weapon system accuracy, and distance from weapon aimpoint to the target. These computations may be applied to point or area targets.

<u>Sortie</u> - In STRAT MISSILER usage, accessible assignment of RVs from a single missile to specific targets.

<u>Specific impulse</u> (ISP) - Thrust produced by a rocket engine when a unit weight of propellant is consumed per unit time. Specific impulse indicates the efficiency of the propulsion system; it is computed as the ratio of thrust to propellant flowrate.

<u>Supplementary aimpoint</u> - Aimpoint that can be used instead of the primary aimpoint to attack a set of installations. Low-yield supplementary aimpoints (L-supps) are designed for weapons whose effectiveness is not sufficient for eligibility to the primary aimpoint; multiple L-supps must be attacked to achieve the same result as attacking the primary. High-yield supplementary aimpoints (H-supps) are designed for weapons whose effectiveness exceeds the maximum value allowed for eligibility to the primary; attacking a single H-supp is equivalent to attacking multiple primary aimpoints.

<u>System range capabilities</u> - See maximum range and minimum range.

Target - General term designating either an aimpoint or an installation.

Target island - A contiguous geographic area defined such that any weapon designated as eligible for a DGZ within that area will not cause collateral damage to any installations outside the defined area.

Target type - A two digit integer assigned by the user to each target based on its characteristics. Target type distinguishes targets within a category; for example, if category 1000 contains all ICBM silos, then target type 52 might denote those silos containing SS-9 missiles.

Throwweight - The vehicle weight after the last booster stage of a missile has burned out and separated. It includes RVs, MIRV post-boost vehicle, penetration aids, and the like.

Thrust - Forward-directed force developed by missile's propulsion system. Thrust loading is the ratio of the missile's gross weight to its thrust.

Tiered target system - A target system in which sets or layers of aimpoints covering the same installations have been defined for different effectiveness weapon systems. These layers of aimpoints are related in a tiered fashion with pointers indicating relationships among different layers whose aimpoints affect the same installation or group of installations. See also primary-supp complex, primary aimpoint, supplementary aimpoint, and hit.

Time of flight (TOF) - Duration of RV flight from launch until detonation.

Time of flight uncertainty (TOTU) - STRAT MISSILER does not compute TOFU for a fixed-site missile; the user may include TOFU as part of the launch slot size or may enter TOFU directly in Category 210 of the data base. The Model computes a TOFU for mobile-based missiles that reflects the size of the launch patrol area. The Assignment subsystem tests sortie accessibility from each Launch Reference Point(LRP) and computes the corresponding TOF. TOFU is then computed as (TOF(max)-TOF(min))/2.

Total force - Complete set of either land- or sea-based missiles (ICBM or SLBM). The total force of land-based missiles includes all fixed-site, trench-based, shelter-based, land area-mobile, and air-mobile missiles.

Time-on target uncertainty (TOTU) - In STRAT MISSILER, TOTU is equal to one half of the possible variation in time of arrival at the target. For a fixed-size missile, TOTU is equal to one half of the launch slot size. For a mobile-based missile that does not control TOTU, TOTU is usually equal to one half of the launch slot size plus the TOFU.

Trajectory - Path of a vehicle traveling through space including atmospheric reentry.

Trajectory shaping - Procedures for determining a trajectory that satisfies mission requirements and does not violate missile constraints.

Uprange - Direction of decreasing inertial range from missile launch point to RV impact point. See downrange.

Value mode - An operational mode of the Allocation and Assignment subsystems. When operating in this mode, each subsystem distributes or assigns weapons while attempting to maximize the total value of the aimpoints that are covered. Allocation accounts for differences in weapon probability or arrival while distributing weapons, but does not consider differences in single-shot kill probability. Neither Allocation nor Assignment compute compound damage expectancy or expected value destroyed; the Analysis subsystem computes these measures of effectiveness.

Value point system - A convention that assigns a point value to all aimpoints and installations associated with a target system. The most important targets or installations receive the most points; differences in point value between various categories of aimpoints or installations are arbitrary. Value points associated with aimpoints are used in the value mode execution of the Allocation and Assignment subsystems, and by the Analysis subsystem in computing EVD by aimpoint. The Analysis subsystem also, upon user request, uses the installation value points to compute EVD.

Vulnerability number (VN) - A number used to indicate the relative resistance of an installation to damage from a blast wave produced by a nuclear weapon.

Weapon - Reentry vehicle or aircraft-delivered weapon (bomb, SRAM, etc.).

Weapon mix - Ratio of weapon types distributed over a group of aimpoints, based on the number of hits achieved by the weapons. A single weapon assigned to a primary aimpoint produces one hit, while one weapon assigned to an H-supp produces several hits.

Allocation and Assignment accept a user input defining the desired weapon mix against a planner segment. For example, the user might specify a weapon mix for 1:1 for Mark 12 and Mark 3 weapons against a planner segment; in this case, it is probable that many more Mark 3 weapons will be needed to satisfy the hit goal of 50% because they will be used against L-supp aimpoints.

Weapon system - A general term denoting either a missile system or the set of all aircraft-delivered weapons; only the Allocation subsystem deals with aircraft-delivered weapons.

Withhold sortie - Identifier accepted by Scheduling subsystem; sorties identified as withhold in a scheduling planner segment will be assigned to the best available launch slots, subject to the constraint that these assignments must not cause delays for any other sorties in the planner segment that are not identified as withhold. Note that a "withhold sortie" is not withheld from the scheduling process. See also preferred sorties.

Yield - Total energy released in a nuclear explosion, usually measured by the estimated equivalent amount of TNT required to produce the same energy release. If the user does not supply a value for RV weight, then STRAT MISSILER computes a default value for weight using a relationship between weight and yield that is based on historical data.

REFERENCES

1) "Advanced Missile Computer Model (AMM) System/Subsystem Specification", Logicon R:OAD-78012-AMM 221, 10 August 1978 with Update

2) "Advanced Missile Computer Model (AMM) Program Specifications: PS-01 to PS-06", Logicon R:OAD-78001-AMM 212 to R:OAD-78006-AMM 216, 15 January 1978 (updated 15 March 1978); and PS-07, R:OAD-78013-AMM 222, dated 15 March 1978

3) "Request for Proposal, Advanced Missile Computer Model", F04704-76-R-0023, Department of the Air Force

4) Physical Vulnerability Handbook - Nuclear Weapons, AP-550-1-2-69-INT, Defense Intelligence Agency, Change 1 Change 2, Change 3, Addendum, 1 June 1969 (CONFIDENTIAL)

5) Mathematical Background and Programming Aids for the Physical Vulnerability System for Nuclear Weapons, Defense Intelligence Agency, DI-550-27-74, 1 November 1974 (UNCLASSIFIED)

6) Capabilities of Nuclear Weapons (U), DNA Effects Manual Number 1, Parts I and II, 1 July 1972 (SECRET RESTRICTED DATA)

7) Department of Defense Dictionary of Military and Associated Terms, The Joint Chiefs of Staff, JCS Publication 1, 3 September 1974

8) "Advanced Penetration Model, Data Management System, Volume V: IBM 360 Version Model Operation", Boeing D162-10328-5, 15 October 1971

9) "Advanced Penetration Model, Data Management System, Volume VI: Parallel I/O Mode of DMS Operation", Air Force Studies and Analysis, 12 October 1973

10) "Advanced Software Prototype (ASP) Engineering Design Document", Logicon R:OAD-76049-ASP170, 30 September 1976

11) "Program Operations Manual, Timing and Resolution Modules for the Combined Strategic Missile Forces, Volume I: Description of Operations, Batch MAPM 211.5A1 and Interactive MAPM 1211.5A Programs (U)", TRW MAPD 6254, October 1976 (TOP SECRET)

12) "Program Operations Manual, Timing and Resolution Modules for the Combined Strategic Missile Forces, Volume II: User's Guide, MAPM 211.5A-1 (U)", TRW MAPD 6255, October 1976 (SECRET)

13) "Force Scheduling: Software Design Exercises (U)", Logicon R:OAD-76003-SAG144, 9 February 1976 (SECRET)

14) F. Glover, D. Karney, D. Klingman, "The Augmented Predecessor Index Method for Locating Stepping Stone Paths and Assigning Dual Prices in Distribution Problems", Transportation Science, Volume 6, Number 2, May 1972

15) "The Hungarian Method for the Assignment Problem", Naval Research Logistics Quarterly, Volume 2, Number 1

16) H. W. Kuhn, "Variants of the Hungarian Method for Assignment Problems", Naval Research Logistics Quarterly, Volume 2, Number 2

17) SALT Lexicon, U.S. Arms Control and Disarmament Agency, ACDA Publication Number 71, 1974

18) U.S. Air Force Glossary of Standardized Terms, A.F. Manual 11-1, Volume 1, 2 January 1976

19) C. Thomas, "Estimation of Nuclear Weapon SSPK vs SSBNs (U)", Memorandum for the Record, AFSA, 1 November 1977 (CONFIDENTIAL)

20) Kazar Kazarian, W. C. Koerner, D. P. Stewart, "The P-Star Technique and its Application to Inertial Guidance", AIAA Conference Paper 73-837, 20 August 1973

21) "Countermilitary Potential: A Measure of Strategic Offensive Force Capability (U)", W. A. Barbieri, RAND R-1314-PR, December 1973 (SECRET RESTRICTED DATA)

22) "Advanced Reentry System Fratricide (U)", Kaman Sciences Corp., K-6205-76-24-FR (ADC 013305), December 1976 (CNWDI, SECRET-RESTRICTED DATA)

23) "The Combinational Mathematics of Scheduling (U)", Ronald L. Graham, Scientific American, Volume 238, Number 3, March 1978